COMPUTER NETWORKS IN ELEMENTARY AND SECONDARY EDUCATION

by

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October 16, 1987

This document was prepared under a contract with the Office of Technology Assessment, Congress of the United States, for the assessment, *Power On: New Tools for Teaching and Learning*. The conclusions are those of the author. The document does not necessarily reflect the analytical findings of OTA, the Advisory Panel, or the Technology Assessment Board.

J952-24

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INTRODUCTION

Elementary and secondary educational institutions are beginning to make use of the communications capabilities of computers. Using personal computers and modems (communications devices that allow computer information to be transmitted and received over normal voice telephone lines) many classrooms and education-administration offices across the country and around the world are now undertaking network activities such as electronic mail, information retrieval, computer conferencing, and subject-oriented workshops.

A major advantage of computer networking for education is that the technology is relatively inexpensive and well-proven in home and business settings. An investment of $2000 or less--for a personal computer, a modem, and word-processing and telecommunications software -- can enable a school to participate in networking activities (assuming that the school already has a telephone line).[1] Additional and continuing costs vary with the

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[1] Networking does not require a sophisticated personal computer, nor is it necessary to have a machine that runs word-processing software that is compatible with all others with which one hopes to communicate. Since messages are converted to ASCII (American National Standard Code for Information Interchange) characters before transmission, most computers are usable in networking operations, even ones costing as little as $150. Thus a <u>minimum</u> investment in equipment and software might currently look like:

computer:	$150
TV monitor:	200
cassette tape recorder:	20
modem:	200
word processing SW:	free (public domain)
communications SW:	free (public domain)

types of activities in which the school elects to participate. Monthly bills may be generated for long-distance telephone charges and for subscriptions to various services; these costs are proportional to usage[1] and so largely under the control of school administrators.

Once a school has the basic equipment and software, there is a rich variety of activities currently available for teacher and student involvement:

- Many schools and interested individuals have set up local electronic bulletin-board systems. These facilities dedicate a personal computer and a telephone line, for at least part-time, to serve as a community forum for posting messages and information about school activities (e.g. meetings, current issues, tips on teaching methods) and computer use (e.g. newly available software and hardware, tips on particular systems and packages); users may trade software ("uploading" -- posting software on the board for others to use -- and "downloading" -- snatching posted software for one's own use); some bulletin-boards also have special software features that facilitate more extended exchanges on a particular topic, usually termed "conferences."

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total: $570

[1] Of course, such a minimum investment will mean that the uses a school may make of its computer are severely restricted.

- "Computer conferencing" software has been developed in some networking systems into sophisticated environments for discussion and collaborative problem solving. The two major types of conferencing software configurations (Linear and Circular) and some examples of available systems are shown in Figure 1.

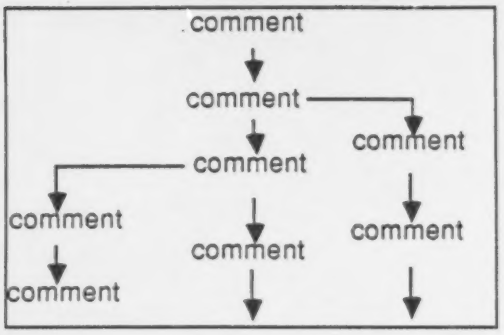
- Some school systems offer lessons over personal-computer-telephone-line-based facilities. These may consist of real-time interactive drill-and-practice or "personalized-instruction" routines e.g. for mathematics (much use of the PLATO system is of this kind), or they may involve an extended local dialogue with the computer and submission of a completed lesson by telephone line to a central location (this is particularly attractive to rural districts experiencing teacher shortages in specialized subjects such as foreign languages or special education).

- Schools may tap into a growing array of government and commercial computerized "databases." These are libraries of electronically-accessable information on a growing range of topics, including current affairs (e.g. Dow Jones News Retrieval Service), bibliographies and abstracts of research (e.g. ERIC or Pollution Abstracts), encyclopedias (e.g. Grolier's Academic American On Line), and career information (e.g. Career Placement Registry or Peterson's College

FIGURE 1

Computer Conferencing Systems

Linear (or Branching)



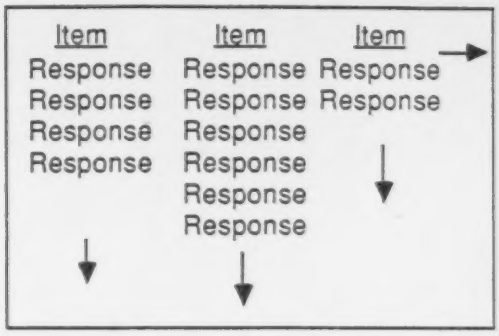
EIES -- The "Electronic Information Exchange System" (EIES) was developed at the New Jersey Institute of Technology in 1977 and is the oldest of the currently available systems. It is ONLY available through NJIT.

PARTI -- Participate (PARTI) is the most widely known commercial conferencing system and is the system available on The Source, Networking Worldwide (NWI), and 'Jnison. In addition to being available on these time-sharing systems, PARTI can be installed on several different mini- and mainframe computers for an organization's internal use.

CoSy -- CoSy is the name of the computer conferencing system developed at the University of Guelph in Canada. It has been licensed for use by a number of colleges and universities in the U.S. and Canada. The "Byte Information Exchange" (BIX) uses a customized version of CoSy and is currently the only commercial application of this program.

NOTE: Traditional "Bulletin Board" systems are also organized in essentially a linear fashion. The more advanced bulletin board programs can be configured to emulate some of the basic features of a computer conferencing system -- but they lack the sophistication necessary for serious use for group communications in organizations, universities, and professional associations.

Circular (or Two-Dimensional)



CONFER II - Confer II was developed in 1977 at the University of Michigan and is commercially available on a time-sharing basis from Wayne State University in Detroit, Michigan. Confer II was the original "circular" conferencing system and is very friendly and powerful. Its principle disadvantage is that it is only available on a proprietary operating system (MTS) from a small number of universities.

CAUCUS - CAUCUS emulates Confer II and offers virtually all of Confer's features. Versions of CAUCUS are available for a wide variety of computers and operating systems including MS-DOS and Xenix-based microcomputers, minicomputers running UNIX, DEC computers running the VMS operating system, Prime computers running Primos, and IBM mainframes with the VM/CMS operating system. CAUCUS is also available for the more popular Local Area Networks. Dialcom is the only major time-sharing service currently offering CAUCUS to its customers. CAUCUS is regarded as one of the easiest of the "full featured" computer conferencing systems to learn and use.

VAX NOTES - Digital Equipment Corporation (DEC) released its own computer conferencing system, known as VAX NOTES, a year ago and it is regarded as a powerful system. Its principle disadvantage is that it is very difficult for people to learn unless they are already familiar with the DEC VMS environment. Currently, there are no major time-sharing companies offering VAX NOTES on a commercial basis -- but the program is expected to gain acceptance for internal use by organizations already operating DEC computers.

SUMMARY COMPARISON

Linear and branching systems offer users the flexibility of starting new conferences that branch out into new streams of discussion -- but often this makes it very difficult to follow a discussion over time or to trace the development of ideas through the multiple branches that may have started. Branching systems have become popular with individuals who are primarily interested in participating AS INDIVIDUALS.

Circular and two-dimensional systems offer flexibility AND the ability to sustain focused discussions that are easy to track over time. They also permit discussions to be cross-indexed and searched. For these reasons, circular and two-dimensional systems are preferred for organizations and educational institutions where it's important to keep groups together and discussions focused and purposeful.

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Database). Subscription to these services can be expensive; charges are based on connect time and may involve telecommunication-line charges, so school budgets constrain how much students and teachers may have access; as well, each of these databases may have its own set of commands for searching and retrieving information. Some network service institutions, as we shall see, are providing "gateways" to different databases, allowing users to connect to a local computer that switches between a number of these services, saving users time and money.

- As experience is gained in the uses of computer networking in education, a new range of activites is becoming available to exploit the potential of the technology to facilitate collaborative work among students and teachers. Cooperative science and writing projects for students are being developed by some groups; curriculum research and development and cooperative research and writing among teachers and administrators are new frontiers of collaboration being explored with this technology.

Some people involved in or observing this effort see it as truly revolutionary and likely to produce profound social effects -- ultimately in how people work and how communities are

organized, as well as in the processes of education.[2] Many others see as it as a potentially interesting adjunct to other media -- books, television, other uses of computers -- in the evolving modern classroom.[3] Still others see communication as the most problematic of the applications of computers in education because of the remaining personal and institutional difficulties peculiar to networking.[4]

In any case, the technology is now so commonplace in schools and supporting offices,[5] that potentially, thousands of elementary and secondary educational institutions and millions of students can engage joint interests using this medium. Moreover, significant projects are now underway demonstrating that, under favorable conditions, teachers, administrators, and students can find practical tools and rich learning experiences in educational computer communications.

The range of new projects, both in efforts that are institutionally well-organized and funded, and in ones that are informal and individually motivated, is impressive. The long-

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2. James A. Levin, et al., "Education on the Electronic Frontier: Teleapprentices in Globally-distributed Eductional Contexts," Contemporary Educational Psychology, vol. 12, 1987, pp.254-260.

3. Michael D. Waggoner, "A Forecast for Technology and Education: The Report of a Computer Conferencing Delphi," Education and Technology, vol.19, No.6, June 1986, pp.92-96.

4. Henry J. Becker, personal communication, September 1987.

5. Henry Becker found that 25% of high schools and about 4% of elementary schools had one or more computers equipped with modems in 1985 (personal communication, September 1987).

term success of any approach is unproven at this time because the technology and its potential are so new in education, but great excitment is now common among educators and students bitten by the networking bug.[6]

If one accepts the premise that modern society is entering an "Information Age," optimism is justified when one observes students' hands-on involvement with computer networking. The educational practices implicit in the pragmatic philosophy of John Dewey[7] and the developmental psychology of Jean Piaget[8]

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[6] This enthusiasm for networking is undoubtedly related to the often-reported generally enthusiastic reaction to computers in education. It is not clear to what extent this phenomenon is merely a reaction to the novelty and relative scarcity of computers in schools (few schools have more than about one computer per classroom), or whether fascination with the technology can serve as a long-term basis of motivation to participate in educationally rewarding computer experiences. (See Lawrence J. Fedewa, Search: Do Computers Help Teachers Teach? (Washington DC: National Education Association, 1987), p.11.) More research is needed to understand the factors affecting "computer enthusiasm."

[7]. Dewey's educational philosophy emphasizes the importance of connecting subject matter to concrete activities, so that a child is not asked to learn mere abstract facts but practical ways of organizing and adapting to his environment. See, for example, John Dewey, Democracy and Education: An Introduction to the Philosophy of Education (New York: The Free Press, 1967), and John Dewey and Evelyn Dewey, Schools of Tomorrow (New York: Dutton, 1962).

[8]. "The principle goal of education is to create men who are capable of doing new things, not simply of repeating what other generations have done -- men who are creative, inventive, and discoverers. The second goal of education is to form minds which can be critical, can verify, and not accept everything they are offered. The great danger today is of slogans, collective opinions, ready-made trends of thoughts. We have to be able to resist individually, to criticize, to distinguish between what is proven and what is not. So we need pupils who are active, who learn early to

appear to be extensively doable with this technological ensemble; experience with personal-computer communication arguably is the soundest practical preparation for work and community involvement in a projected future of ubiquitous computer technology.

Moreover, teachers and administrators now find themselves able quickly to share information across as well as within traditional institutional boundaries, thus opening up significant new opportunities for collaboration and systematic research. Indeed, some current efforts suggest that barriers of geographic isolation, race, socio-economic status, physical handicap, and age can be overcome in computer networking projects. Caution is necessary in assessing this new technology precisely because of its potential to alter traditional patterns of public education: one can expect institutional and personal resistance where networking threatens to upset or bypass existing lines of authority or to instill changes in curricula that are not validated by accepted evaluation techniques such as standardized tests.

We now examine a sample of current efforts illustrating uses that this new educational technology can support when it is offered in institutionally-organized projects.

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find out by themselves, partly by their own spontaneous activity and partly through material we set up for them; who learn early to tell what is verifiable and what is simply the first idea to come to them." From Jean Piaget, "Development and Learning," in R.V. Ripple and V.N. Rockcastle (eds.) Piaget Rediscovered (Ithica NY: Cornell University Press, 1964), p.5. See also, Jean Piaget, Science of Education and the Psychology of the Child (New Yor

INSTITUTIONALLY-ORGANIZED NETWORKING PROJECTS

TEACHER-LINK

Computer networking is being tested as a tool for elementary and secondary teacher education. The University of Virginia is developing a system called Teacher-Link that will make electronic communication available in public school classrooms where student teachers are working. Student teachers undergoing their initial confrontations with running a classroom will be able to communicate among themselves and with faculty at the University of Virginia. They can compare notes and get experienced help as problems crop up, mitigating the isolation that many teacher recruits feel. The system will also support discipline-specific computer conferences, for example in English and social studies, to aid students in developing curricula and lesson plans, and in learning the skills for working through particular classroom difficulties.

Initially, the system will connect student teachers in two Virginia public school districts with a campus-wide messaging system at the University of Virginia. Within three years, the organizers hope to be able to serve all the university's student teachers in their field sites, which would involve seven public-school districts. Eventually, every student teacher in the State of Virginia may have access.

During the first three years of the project, IBM is loaning the University approximately $1 million worth of equipment,

including a mainframe and 135 portable computers; upon successful completion of the project, these machines would be donated to the University. Metasystems Design Group, Inc. is providing the CAUCUS conferencing software system, which sells for $15,000; this software will support student and faculty and participation in a variety of computer forums. Centel is providing a grant to cover telephone services. Public school sites will have to run telephone lines to participating classrooms, which will cost about $25 on average.

The immediate value of an on-demand facility for asking questions and solving problems is obvious to students teachers and education faculty alike. This impetus to involvement, the organizers hope, will encourage users to develop an interest in other applications of networking, such as participating in conferences and collaborating in curriculum development and research. The computer-networking infrastructure that is being put in place at the University of Virginia will be powerful and flexible enough to support activities ranging from elementary-student projects to advanced faculty research and collaboration.

ILLINOIS STATE BOARD OF EDUCATION ADMINISTRATIVE SERVICES NETWORK

Computer networks are also being put into place to serve the operational needs of public school administrators. For instance, the state of Illinois has developed a network, based on PLATO* software and run on a mainframe computer located at the University of Illinois, to facilitate control and information flow between the State Board in Springfield and the 18 regional service centers that serve the 1007 public school districts across that state. Service-center staff, who serve as an administrative bridge between the State Board and the individual school districts, dial-up the network daily with personal computers on toll-free lines to obtain instructions and information on budgeting and other policy matters, to get announcements of current programs in administrator and teacher training, workshops, and consultant reports, and to access specialized databases on innovative educational practices, youth services, and bibliographies of particular interest to Illinois educators. The State of Illinois currently spends approximately $20,000 per year on this computerized administrative service; this covers hardware and software purchases, communications costs, and specialized programming of system-specific databases; it does not include salaries of system operators.

At this time, the regional service centers are beginning to

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* PLATO is a registered trade mark of Control Data Corporation; PLATO was developed by the University of Illinois, which retains the right to use this trade mark.

develop computerized links to the school districts. It is anticipated that, eventually, such information as district budget accounts, attendance figures, and student records will flow within the system via electronic mail. An obstacle to using electronic means for passing some kinds of information is the need for an official signature on records. State legislation may be necessary to enable the wide use of computer networking in the sphere of administrative information. An alternative being explored is facsimile transmission, but the cost of equipment is deemed to be prohibitive at present. In the mean time, electronic mail is proving valuable to Illinois state education administrators in coordinating activities and anticipating the need for timely action by responsible officials.

The University of Illinois has long been interested in computer use in education; it developed the familiar PLATO CAI system of interactive instruction. This system is now extensively used in college, industry, and government training programs. PLATO has been embraced to a lesser extent by elementary and secondary schools because the cost of dedicated terminals and central-host computer access has been beyond most local-school budgets.[10] The University of Illinois is now involved in a major revision of PLATO that promises to reduce costs by 75 to 90 percent, or from approximately $240 per

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[10] U.S. Congress, Office of Technology Assessment, Informational Technology and Its Impact on American Education, (Washington, DC: U.S. Government Printing Office, November 1982), p.130.

terminal per month to $30-60 per terminal per month, depending on the number of local sites that can cooperate on leasing a telephone line to the central host. The new system is called NovaNet.[11] Local cooperative sites are being encouraged to invest in a satellite downlink, for about $15,000, which will give access to an expanded range of PLATO services such as sophisticated graphics. Instead of dedicated terminals, the new system will allow classrooms to use a wide variety of microcomputers. Illinois state education officials hope to use NovaNet as the technical base for an integrated range of network services for public school administrators, teachers, and students.

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[11] NovaNet is a service mark of University Communications, Inc.

NEWS ACCESS

Computer networking may also be used as an adjunct to other classroom activities -- integrated into a multimedia mix so that classrooms may have fast and efficient access to an expanded range of curriculum materials. An example of this kind of use is found in the new project being sponsored by Turner Educational Services (a division of Turner Broadcasting) and the National School Boards Association's Institute for the Transfer of Technology to Education. Here, schools are offered a subscription service consisting of a license to videocassette-tape and retain copies of a Cable News Network (CNN) weekly one-hour television feature called "The Week in Review." In addition, the service provides classroom activity guides produced in conjunction with the video service and made available for downloading through CompuServe.

In a pilot issue of the Classroom Guide, suggested student activities and supporting materials included:

- A digest of the different stories covered in the cablecast (sixteen in all) and suggested concepts and questions for study and discussion; along with the digest, an index of story titles and times of appearance in the program is provided. The range of subject matter -- from the Persian Gulf situation, to the AIDS epidemic, to the anniversary of the Golden Gate Bridge -- presented issues likely to pique the interests of many students.

- A separate annotated index organizes the stories according to areas of curriculum -- social studies, language, math, general science, art, geography -- and in some instances suggests books to supplement the video material.

- A guide to help students organize their own video production of the news, suggesting divisions of duties among students (producers, researchers, writers, tape editors, anchor-persons), techniques for integrating their own productions with the video materials provided, and a list of stories from a number of episodes of "The Week in Review" that they may use to organize and perform a "documentary" on a subject that has been in the news for several weeks.

- The text of an interview with a "Week in Review" producer that helps students understand some of the responsibilities and problems of producing a news program, including the selection of stories, journalistic ethics, and video-journalism as a career.

- A set of mathematics word problems that use facts about the Golden Gate Bridge to explore math concepts and applications.

As well as downloading of video material and classroom guides, News Access is planning to offer a bulletin board service

with which classrooms may contact CNN to supply feedback and ask questions; students will also be offered contests in which they can exhibit their own work. Potentially, the News Access system could provide a continuing forum for discussion of current events among classrooms and for the development of interest and skills in news production.

The basic cost of a subscription to the service is $25 per week per school; there are flexible rate scheduals available for long-term or multi-school use. The subscription includes a license to tape the program and access to the Classroom Guide. Hardware requirements are a videocassette recorder, television, computer, modem, and telephone line. Additional expenses include appropriate communications software, a subscription to CompuServe, and possibly long-distance line charges if there is no local CompuServe node. Beginning in September 1987, News Access will be used in about 60 schools in some 30 school districts.

There are three intriguing features about News Access that suggest that it may be a particularly engaging and useful application of computer networking. First, almost all students are familiar with, and are at least occasional users of, television news. Thus, the integration of this medium into the classroom where television can serve as a focus for a broader array of activities -- reading, discussion, writing -- may make the familiar world of television watching a bridge to the development of participant skills. Second, the range of news

stories that appear weekly on "The Week in Review" can offer both a broad array of curriculum-relevant subject matter and a set of issues that appeal to a diverse population of students. Third, the multimedia nature of News Access may help teachers and students become familiar with and cognizant of the potentials and limitations of different forms of communication.

LEARNING LINK

The multimedia approach is characteristic of another interesting system of educational computer communication, one developed and operated by WNET, the Public Television station in New York City. Originally intended primarily as a tool to facilitate the use of public television, Learning Link--operational now for over two years and serving more than 500 schools in New York, Connecticut, and New Jersey -- has expanded the scope of its content to encompass five service components:

1) An electronic-mail service for subscribers, with which users may send private messages to one or many individuals on the system. At sign-on time, users are alerted if they have new mail; they may delete messages they have read or save them for later review.

2) Schedule and program information for WNET/THIRTEEN broadcasts, including:

- summary information on specific upcoming programs, user-searchable by time, title, curriculum subject area, or grade level, so that educators may plan viewing or taping;

- more extensive key-word-searchable information on program series (such as Nova or Nature) including curriculum applications, recording rights, availability of ancillary materials, and projected air dates for future episodes.

3) Computer-conference forums for teachers to share information and opinions on common professional concerns. Some of these forums are run by WNET staff, but teachers themselves are encouraged to create and operate their own conferences. Some that are currently in progress include ones operated by the Children's Television Workshop, a New York City history teacher expert in the Civil Rights Movement, and the Dairy Council on nutritional issues. Short mail messages, longer text files, and small databases such as bibliographies are accomodated separately to speed conference participants' interaction.

4) Gateways, via a local call or a toll-free 800 number, to other computer-accessable services, including:

- Inforsearch Scholastic Database, a commercial database service, providing on-line access to ERIC, Grolier's Academic American Encyclopedia, Webster's New World Concise Dictionary, several other educational forums and tools, and transcripts of some PBS programs such as the MacNeil/Lehrer News Hour and Nature;

- Einstein, an Addison-Wesley commercial service, providing searchable files from major newspapers, Information Science Abstracts, the Library of Congress MARC Books File, the National College Databank, and others sources;

- the Big Apple BBS, a public bulletin-board service run by the New York City Board of Education, in which students and educators discuss research findings, share problems and solutions, and reflect on the uses of computers in education.

Learning Link gateways provide users with several advantages over direct access to these services:

- they help new users pick services that have proven most

useful to the education community out of the many that are now available on-line;

- novice users are given help in learning to exploit these services more effectively; a community of experienced users is available to share ideas and procedural skills;

- users connected through Learning Link avoid toll-call charges; facilities and assistance will be provided in the future to reduce search costs for commercial services by preparing searches ahead of time and using high-speed communications devices resident on the Learning Link system to interact with the commercial hosts.

5) A product listing service, which alerts users to commercial products such as hardware, software, and printed materials available at substantial discounts. Originally Learning Link allowed users to make transactions on-line, but this did not work well within the framework of WNET's mission to serve as an originator and conduit for public information; also most users were unable to make purchases on-line because of institutional purchasing rules; Learning Link is therefore revising this service to provide on-line catalogues from selected vendors, and WNET will not be

involved in transactions. A second service provided in this section, the Culture Catalogue, alerts users to museum resources and cultural organizations with special services for schools, including permanent and temporary exhibits and performances.

Learning Link is a powerful example of how a computer communication service can become the coordinator of an impressive array of educational activities in a range of media forms. Moreover, the technology base of Learning Link is impressively simple -- the central-host system uses an IBM AT personal computer and twelve telphone lines to serve all its patrons. At the school level of operations, the multimedia nature of Learning Link has encouraged many educators to center activities in the domain of the school library/resource center, where a relatively inexpensive personal computer and a single phone line can be dedicated to computer-network access. But the range of services offered, and the availability of individual professional subscriptions, is encouraging individual teachers, computer resource personnel, and administrators to use Learning Link as a means of professional communication and for planning curricula and coordinating student activities. The low cost of subscriptions -- a flat $48 per year for an individual, or $165 per year for a school, which includes one student and five teacher passwords -- puts Learning Link well within the budgets of most schools that have the computer and modem equipment (there

are additional connect charges for the commercial services offered through Learning Link gateways). Moreover, WNET has contracted with AT&T to provide communications terminals for less than $250 each that allow users all the networking capabilities of Learning Link.

Its connection with public broadcasting also makes Learning-Link a potential model for spreading educational networking services nationwide. In fact, the Corporation for Public Broadcasting has provided WNET with funds to evaluate Learning-Link services and to study the feasibility of establishing similar systems in affiliation with other PBS stations and/or state education authorities. WNET is in the process of contracting with a dozen locations to provide software, training, and Learning-Link databases for the establishment of new local educational-network services.

THE INTERCULTURAL LEARNING NETWORK

An important dimension that computer networking adds to educational communication is in its potential for bringing together people from distant locations around the world to work together on a common project. Faculty at the University of Illinois (Urbana-Champaign), the University of California (San Diego), Aoyama Gakuin Women's University (Tokyo), and Hebrew University (Jerusalem) have collaborated to develop personal computer-based activities in which geographic distance and cultural differences become useful devices to focus student interest. International networking provides depth to the study of the natural and social sciences and scope to the development of written communication skills.

Using public dial-up satellite links (Telenet) and a commercial information utility (The Source) to pass electronic mail messages, the Inter-cultural Network has linked classrooms in four states and three foreign countries. Students in upper elementary, middle, and high schools work together on projects in which they compare observations of the different ways that local people handle problems and organize activities that are common around the world.

For example, a set of sites in Israel, Japan, Mexico, Alaska, California, Connecticut, and Hawaii were selected because each had problems with local water supplies. Students collected information on how their localities obtained, purified, stored,

and distributed water. They shared their descriptions via electronic mail with the other sites. Next, students noted the similarities and differences in how water resources were handled. They used e-mail to ask questions and obtain details on specific procedures at different sites. Then the students wrote and shared reports on whether and how their localities might adopt some of the solutions that distant places used to deal with water supplies. One school in California invited in a local municipal official and quizzed him quite sharply on how and why particular ideas were or were not used.

As well as a resource for elementary and secondary students, the Intercultural Network is a resource for research and teacher training in the participating universities. An important aspect of networking activities is that a record is kept of the exchanges among project participants, so that researchers and teacher trainees may analyze, after the fact, the progression of activities that grow in the course of a project.

The Intercultural Network is stimulating a number of exciting lines of inquiry and innovative ideas. Researchers are experimenting with activities in which students may design, implement, and report their work on a continuing basis. Tele-science fairs, computer newswires, and electronic science journals are some examples of the types of forums that students may participate in, developing and sharpening their skills in observing human and natural events, in writing articles and responses ("letters to the editor"), and in cooperating and

competing in world-wide contexts. Teachers, both in elementary and secondary classrooms and in colleges and universites, may use these activities as a focus for hands-on involvement in the processes of learning and sharing knowledge. Practical and familiar phenomena serve as the focal subjects of activity. For example, projects are planned or are in progress on such activities as:

- comparing the boiling point of water at different sites, asking students to hypothesize explanations for differences, such as altitude or water purity;

- comparing local severe weather phenomena and indications to watch for in different locations;

- comparing eating preferences and the reasons for these habits among people in different cultures;

- comparing pollution problems and solutions in different settings;

Organizers hope that these computer networking projects may be used to teach the basic techniques of science and the attitudes of scientists toward natural phenomena. They may also encourage an appreciation of the differences among people.

Networking can also show both children and adults the difficulty of basic human problems and the need for and value of active participation in community affairs.

The usefulness of these activities depends on their appeal to the interests of participants of many ages and backgrounds. Therefore, the organizers of the Inter-cultural Network emphasize the importance of providing a range of activities that allow the young and timid user, as well as the experienced enthusiast, to get involved.

One organizer estimates that the cost to a school -- one which already has a computer and modem -- for active and continual involvement in a system such as the Inter-cultural Network may be as little as $50 per month, which includes the price of an account with an information utility such as The Source, and the supplies needed to involve one or more classrooms in a set of projects. Telecommunications charges are kept low by using a dial-up network with a local node and communicating when the rates are cheap, at night or on week-ends. Messages are sent and received in batches at the convenience of users.

KIDNET

Just as computer networking can extend the reach of educational activities to create international forums for science learning, as we have seen with the Intercultural Network, so too this technology can extend the scale of student activities, making possible the organization of projects involving measurements that can have real significance for science itself. An example of how this is occurring is seen in the Kidnet project under development by the National Geographic Society and the Technical Education Research Center (TERC). Using fairly inexpensive technology -- a central-host personal computer (an IBM AT clone which cost about $4000), a single phone line, an electronic mailbox on the Telenet Telemail host computer, and remote Apple II-GS microcomputers for school telecommunications -- Kidnet is being developed as a science teaching and performance infrastructure for schools.

In a pilot project on acid rain, fourth- through sixth-grade classes in 31 schools in nine states completed an instructional unit on acid and base chemistry, then collected and measured the pH of rain samples. They then shared their data over the microcomputer-based network. The measurement activities were a focus for helping the students understand the processes of science, emphasizing the cooperative and public nature of the methods and results.

National Geographic has ambitious plans to expand Kidnet to

thousands of schools. After additional pilot testing -- at some 200 sites by January 1988 -- they hope that eventually up to 25% of the nation's school districts, and many classrooms in Canada, will integrate Kidnet activities into their yearly science curricula. Subject matter is slated to focus on areas of science that are common topics for upper elementary grades. Examples include weather forecasting, water pollution, food production, and the spread of diseases like the flu. In addition to science, Kidnet curricula will support activities in geography, social studies, and health. Kidnet materials, including access to network activities and an array of printed goods such as National Geographic maps and photos, will be available for about $1.50 per student. Additional curriculum units will be developed as the system expands and planners and users gain experience with applying networking to data collection, analysis, and interpretation. For advanced students and teachers, various conferencing forums will be offered for the planning of new KIDNET projects and the evaluation of networking activities; these conferences may also serve as forums for discussing unique emergent scientific events, such as volcanos and earthquakes.

The extensive and detailed pilot work that is going into the design of Kidnet curricula and the organization of Kidnet activities demonstrates another exciting potential of computer-network-based educational projects. Curriculum designers, teachers, administrators, and students are cooperating, on a national scale, in research and development of educational

materials. Valuable insight is being gained in this project, not only of how new curricula can be integrated into use, but also the specific features of materials and activities that contribute to the development of particular scientific skills and understanding among students.

For example, the evaluation of the results obtained in the pilot study on the acid rain project demonstrated that many teachers were having difficulty in working through the post-data-collection phases of analysis and interpretation. The project organizers feel that these aspects are so essential to student understanding of science that they have devoted considerable effort to revamping the materials for these activities. This kind of extensive evaluation of how and why curricula appeal to teachers and students may serve as a model for a broader-based national effort at educational research and development, perhaps along the familiar lines of medical-clinical trails that have been so successful in the health-care sector.

CONFER

The potential of computer communication as a tool in educational research and development has been a key focus of another system, one that was developed by Robert Parnes at the University of Michigan in 1974 and has been in continuous use since 1975. At its inception, CONFER was intended as a means of studying and implementing advanced decision-making procedures in academic organizations. CONFER software is now licensed to three additional universities where it serves thousands of users. At the University of Michigan, alone, over 2000 users access CONFER on a central-host mainframe running the specialized MTS (Michigan Terminal System) operating system software, and paticipate in hundreds of conferences on a wide range of subjects of interest to educators and students. The conferences are used for information exchange, administration, research, and instruction.

A special feature available on conferences run on MTS is a tool called Dynamic Value Voting (DVV). Developed by Merrill Flood specifically for CONFER, DVV provides a structure and methodology for bringing discussion on an impending decision to a vote. The system takes into account a range of factors and alternatives, tabulates the values participants assign to various conditions, and ranks the outcomes of institutional choices (the system may also be used by an individual taking different points of view). The result is a decision-making procedure that is both inclusive of many viewpoints and democratic in outcome.

The use of computer conferencing as a political tool, both to aid the work of education officials, and to teach students concepts of political science and the real human processes behind them, has been explored within the CONFER system. For example, high school students in fourteen states and three foreign countries have participated in simulations of the Arab-Israeli Conflict using the special CONFER application called Interactive Communication Simulations (ICS). Here, teams of students are involved in an exercise in which they assume the roles of political figures and communicate with one another, acting in response to a given scenario and the responses of other players. The simulation requires the students to prepare themselves in advance, and is thus an opportunity for learning library research skills in a context of engaging practical interest. Each participating school has a faciltator -- usually a teacher -- who makes sure that the network is operational, helps students divide responsibilities, and stimulates and paces the discussion. Facilitators themselves are thus challenged to learn the processes of project planning, policy formation, decision making, and evaluation of outcomes.

Interactive Communication Simulations are an intriguing application of computer networking in education because they deepen participants' understanding of political processes. Moreover, ICS is a focus of institutional cooperation. The planning, execution, and evaluation of simulation episodes involves high schools from many locales, as well as University of

Michigan faculty in the School of Education and several departments of the School of Literature and the School of Science and the Arts.

A new simulation exercise is now underway which takes the United States Constitution as the focus of activity. Students assume the roles of prominent public figures from the past 200 years of American history, and are engaging as delegates in a discussion of issues culminating in the drafting and approval a revision of the Constitution. Delegate teams are historically mixed and organized to represent particular orientations towards constitutional matters. The historical sweep of roles encourages participants to draw on a wide range of reading to prepare to represent a personage and a point of view. Debates take place in a number of committees; adoption of particular articles, as well as the whole constitution, will involve a range of voting procedures, demonstrating to participants the nature of political influence.

Several additional simulations are in various stages of development. One will focus on United States domestic public policy, simulating the multi-facited arena within which policy is made and implemented at the federal level. Clearly, a wide assortment of subject matter areas will be relevant to participants, and the excitement of personal involvement and uncertain outcomes will attract the interests of many students to issues of great public concern.

The cost of participation in an ICS simulation for schools

already having a microcomputer and modem is $200 per team per school term, with discounts given for multiple teams working under a single facilitator.

SPECIAL-NET AND OTHER SPECIAL-EDUCATION NETWORKING EFFORTS

An important question often raised by the introduction of computers into education is the extent to which this technology may divide society into "information haves and have-nots." Some efforts at developing computer communication in education demonstrate that the technology can, in some cases, have just the opposite effect, enabling people with handicaps to participate in educational and informational activities where their disadvantages become transparent to other users of the system.

Special-Net, developed by the National Association of Directors of Special Education and operational for seven years, now serving 3500 teachers, administators, and students in special-education programs, demonstrates an additional aspect of computer communication in schools: If there is a particular purpose to be served, and networking provides a unique and efficient way of fulfilling that need, even people who were previously non-computer users can be recruited into regular participation in networking activities. In fact, most of the users of Special-Net have no other experience in computer or data-communications operation.

Services on Special-Net include:

- electronic mail;
- a variety of bulletin boards on topics of continuing interest to the special-education community;
- conferences that bring groups of users together electronically for several days or weeks on particular issues;
- data collection utilities that allow educators to gather and analyze survey information from users;
- specialized databases for the use of special-education administrators and teachers;
- gateways to other computerized information services.

The basic Special-Net subscription costs $200 per year per site, with a $35 charge for each additional password at an existing site. Other costs include connect and information-storage charges that are comparable to commercial services such as The Source; Special-Net subscribers obtain a 7 per cent discount on Telenet long-distance connect charges. Other subscription options include a specially-priced general-purpose

microcomputer with modem and supporting software, plus $300 of prepaid connect time, for as little as $1400.

The National Association of State Directors of Special Education retains sponsorship but has turned over management and operation of Special-Net to a commercial company, National Systems Management, Inc. (NSMI), which provides a number of additional services for Special-Net users. These include: user training; planning, analysis, and system design for local special-education communication needs; and detailed subscriber information to aid in the management and planning of communication operations. NSMI is also developing software that will allow users to create their own searchable databases to be added to the system.

Special-Net is in use by state education authorities in all 50 states. In twenty states, local education agencies subscribe. In addition, Special-Net is used by many federal offices, colleges and universities, private special schools, special-interest organizations, and individuals.

Besides Special-Net, the special-education community is developing a number of ways of using computer communication to serve the educational needs of the handicapped. Several unique features of computer networks lend themselves particularly well to helping people with special needs:

- The editing capability of word processors allows people who have trouble with the mechanical skill of writing to produce

neat copy, indistinguishable from that produced by a person skilled in penmanship; moreover, the preparation of messages is generally done off-line, so that the time it takes an individual to prepare a message is not critical to the communication.

- The isolation that many handicapped people experience can be mitigated by electronic pen pals. The growth of on-line transaction systems, such as home banking and shopping, allow the home-bound to more easily perform tasks that enhance their feelings of self-reliance;

- In rural districts, where those that need special-education services may be so thinly spread that teachers have had to spend a great amount of their time on the road between localities, home or special-school networking can increase the level of services existing staff can provide.

- Special input devices, such as voice-recognition systems, and output devices, such as voice output and CD/ROM-based sign-language instruction systems, are under development that can make special-education materials available on-line to a greater and greater range of people.

GRASSROOTS NETWORKING

In addition to the institutionally organized networking projects mentioned above, many teachers, administrators, and students -- particularly those who are computer hobbyists -- are leading grassroots efforts using computer networking to support educational activities. More than in the shining examples cited above, the long-term usefulness of educational computer networking will be decided in the context of individuals forming personal and continuing commitments to the use and development of this technology: a culture of computer communication is, so many believe, as necessary a foundation for continued interest and development as an efficient technical infrastructure.

There has been an explosion of networking services initiated by individuals in the last few years. The low cost of powerful personal computers and modems, the availability of software to manage a home-based information service, and enthusiasm for communication with a new medium not seen since the childhood of "ham radio" in the 1920s, have encouraged thousands of individuals to open electronic bulletin board systems (BBSs) as community information utilities. These services have proliferated so rapidly that a comprehensive account of them, even restricting the domain to ones particularly concerned with education, is a daunting task. CompuServe lists over 200 such education-oriented systems.

This explosive growth at the grassroots level produces

problems for users as well as for researchers. Attracting and holding a cadre of loyal users to a bulletin board can be difficult; messages often languish unanswered; the discourse on these amateur systems can be surprising, but is often disappointing. The life-span of a particular BBS depends upon the interest and dedication of its operator, an individual whose primary reward is the enjoyment of providing a community service.

Private bulletin-board systems are proliferating because they provide some indispensible services to computer enthusiasts. First and foremost, they are a means of bringing information about new equipment and software to the attention of users; these evaluations, though informal, are generally unbiased and even blunt because informants usually have no alterior stake in the success of a new offering beyond the personal boost when someone credits their opinion. Users also obtain training in the form of advice and tips on the uses of different computer systems from BBSs. Further, the community of computer users is supported as BBSs post announcements of meetings and special events. Also, BBSs often offer public-domain software for downloading, thus expanding the "toolboxes" of many computer users.

The educational community, too, is finding that local, privately-run bulletin boards can provide useful services. As with local BBSs in general, announcements of meetings of interest groups, tips on system uses, and evaluations of new equipment and software form the core activities supported by of education-oriented BBS services. To the extent that a bulletin board is

well-targeted to a group of users with a common interest, such as education, one finds that discussion of topics, beyond computers per se, become richer. Educators, particularly public-school teachers, are beginning to use local BBSs to discuss school policy issues and to engage in planning and evaluation of curricula. Some of the most interesting educational bulletin boards are organized around a particular subject, such as physics, or serve a definite community, such as the handicapped. The key to interesting communication seems to be the formation of a group with a definite focus for whom networking can provide a means of celebrating common interests and solving common problems.

COMPUTER NETWORKING AND EDUCATIONAL POLICY

As with any new curriculum interest vying for the attention and limited resources of the public school community, computer networking must be justified as an investment in competition with other educational pursuits. The economic arguments for capitalizing a productive process by the adoption of new technology generally turn on whether such capitalization can be expected to reduce costs, increase productivity, or result in significant new outputs through the investment. There is evidence that teachers and administrators may increase the productivity of some of their work, for example keeping attendance and grades, working out lesson plans, and compiling standardized test results, using computers. Other educational output -- significantly, the quality of education imparted to students -- is notoriously difficult to quantify; therefore the debate often centers on the assumed relationship between proposed changes in curriculum and the overall goals of public education. In the case of computers, proponents have argued three major advantages to be gained from computerizing public education:

1) Society is entering an "Information Age," therefore students must obtain instruction and experience on the premiere device of the coming age, the computer.

2) The computer is the latest in a series of "learning tools"

that stretches back to the origins of the textbook and before, therefore, so that learning is promoted, students should have the advantage of the latest technology.

3) The computer is a particularly important technology because it is an "all-purpose intellectual tool" -- an "amplifier of the human intellect," therefore students, teachers, and administrators should learn to use computers as personal assistants in the pursuit of all legitimate educational activities.

These same arguments may be advanced in support of computer networking; although, particularly if the third argument is considered persuasive, networking raises questions about how priorities are to be decided in school computer resource use. To the extent that access to computers remains limited, networking must compete with other uses, and thus must be justified on additional grounds.

Three interrelated questions may be posed to help understand the bases on which networking is and may be a good addition to educational practice: Why invest in computer networking rather than in more and higher-paid teachers or better traditional facilities, such as classrooms or science laboratories? What activities can be supported with computer networking that make it a good alternative use of existing school computers? Who stands to benefit from the introduction of computer networking into schools, and will some people tend to be bypassed or left out?

WHY COMPUTER NETWORKING?

Some existing educational goals appear to be well served by computer networking; as well, some additional educational benefits may be expected from the use of this technology:

- Science: Student collaboration on large-scale projects, such as the KIDNET Acid Rain study, can provide opportunities for hands-on work in the actual processes of scientific research. It may be argued, though it has not yet been empirically validated, that student and teacher involvement in such networking activities where real, open-ended, meaningful results are obtained produces superior mastery of the fundamentals of science than the more abstract and pre-determined curricula common to traditional class and laboratory science instruction. Moreover, the curriculum research and development infrastructure that is created to plan and evaluate such large-scale projects as those envisioned in KIDNET may bring a new scientific rigor to the generation of curricular materials.

- Social Studies: Perhaps even more promising than its potential for science learning, computer networking appears to offer substantial benefits to the educational study of social life. Three projects covered in this paper -- News Access, The Intercultural Learning Network, and CONFER--

demonstrate that the scope of appreciation of cultural differences can be significantly broadened. In studies ranging from news and current events, to geographic peculiarities, to the processes of political conflict and compromise, computer networking can, by bringing students and teachers into contact with distant classrooms, offer in concrete, human terms new understanding of social differences and common problems. The development of communications skills, alone, might justify the relatively small cost of involvement in some of these projects; students' practice of community participation may have significant benefits for society as a whole.

- Reading and Writing: Though not the particular focus of the projects covered in this paper, reading and writing skills can be developed within the context of computer networking. Work with school children by researchers at the University of California - San Diego demonstrates that the processes of interpreting messages and formulating replies for the network, particularly because they are usually done "non-real-time" and thus are adaptable to the pace of individual students, appear to provide substantial practical impetus for the sharpening of literate abilities. The establishment of student-directed network publications, such as the Telescience Chronicals, offers the potential of involving many students in practical activities that require and

develop advanced writing and editing skills. Users of bulletin boards and participants in computer conferences, including educators, often praise the written format of discussion peculiar to computer network forums: Writing, so some contend, encourages more careful consideration of ideas before they are offered for discussion.

- Research and Information Retrieval: To the extent that schools are able to afford the connect charges for on-line databases, students and educators will have access to an increasing array of information that is accessable in new formats by computer. Networking activities may also stimulate students to take a more active role in seeking out information in local libraries to support their participation in networking projects. Some educators contend that when research work is tied to a specific purpose that has results that will matter to other people, students themselves are likely to initiate learning of information retrieval skills.

- Art, Music, and Design: Although at present generally unavailable on school networks (with the exception of some specialized systems like PLATO), the graphics capabilities of personal computers are an area of excitement for education. Eventually, given wide-band links to the classrooms -- perhaps based on fiber-optic or satellite

microwave technology -- students may be able to participate in an even wider range of joint creative projects.

- Vocational Education: Networking offers the potential for a new range of job-related training. Students may find opportunities to engage in "teleapprenticeships" in which a worker who uses computer communications in the course of her job agrees to route certain communications and work assignments to the student so that he may learn the requirements of work in a particular field. Considering that more and more jobs involve computer networking as a routine office function, this type of educational opportunity may become quite common.

- Electronic Seminars: Universities and colleges are beginning to offer courses via computer network, sometimes in conjunction with televised lectures. The non-real-time discussion format supported by conferencing software may make it possible to increase the class size for seminars, usually restricted to a dozen people or less in class. Moreover, educational institutions are no longer necessarily tied to a geographic location; new institutional structures will evolve if these efforts prove successful. Public school educators may find the time flexibility and home or office setting particularly conducive to continuing their own education.

- Integrated Learning Environments: Networked computers may be developed into systems that provide an integrated range of activities that respond in a more precise way to the particular informational needs of individuals or groups. Educational research has long recognized that people approach information-seeking tasks with various objectives in mind. One conceptual system recognizes six levels of cognitive functioning that correspond to the information needs people seek to fulfill in self-motivated learning:[12]

1) Awareness: learning basic facts about a new domain of interest;

2) Comprehension: putting facts about a new domain in the context of existing knowledge;

3) Application: using new knowledge to solve an immediate problem;

4) Analysis: using new knowledge to disaggregate and categorize aspects of a domain of understanding;

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[12] B. Bloom (ed.) Taxonomy of Educational Objectives, Handbook I: Cognitive Domain (New York: David McKay, 1956).

5) Synthesis: organizing new knowledge into a solution or a complete response to a domain of interest;

6) Evaluation: testing the outcome of knowledge seeking and organization so as to understand its value in a larger context of usage.

Employing the computer-network capabilities of information retrieval, manipulation, and discussion, users may find that a greater variety of informational activities can be supported than is possible in traditional library or classroom environments. Moreover, computer networking may encourage users to develop new means of advancing their individual and group work to higher levels of integration and a wider scope of understanding and application.

WHAT USES OF COMPUTERS DOES NETWORKING FAVOR?

Assuming that computer resources in schools will remain somewhat limited, the question arises as to how networking may compete with or augment other computer applications. Computer networking can be expected to put some additional strain on computer resource use: Networking may in fact integrate well with other important computer-learning objectives; but it may also cause competition for resources should it be successful in attracting many new users.

The major current student uses of computers include drill and practice (particularly for mathematics but also for language arts), programming languages (Basic, LOGO, Pascal), games and simulations, word processing, and database creation and use. Drill and practice was an early focus of the PLATO network. Networking seems to be a natural extention and application of other computer-based skills and activities. In particular, the learning of word processing skills is given a natural incentive in networking projects. As well, games and databases may become more popular as they are networked; some students may also find new incentive for learning programming as they trade their work with other interested students. In general, the widened participation in computer-related activities made possible by networking increases the chance that students will find others with common interests, with whom interaction is mutually stimulating.

Teachers and administrators also may find the expanded horizons of computer networks stimulating. Electronic mail is a basic communications format that is growing in popularity among educators. Whether on local bulletin boards or on national computer conferences, professional interaction is provided with a range of new forums for exchanging ideas and collaborating on educational pursuits. Distance teaching, which has been implemented with some success using television, may become another significant use of computer networks.

The fact that relatively few teachers and administrators have heretofor been actively involved in intensive use of school computer resources means that competition among uses and users has not been a major problem. However, should the enthusiasm for educational computing spread this competition for local resources can be expected to intensify; allocating priorities in the use of computers, printers, modems, telephone lines, connect time, software, training, and professional assistance would become a more contentious issue, unless schools could put more money into computing.

WHO WILL BE INVOLVED AND WHO WILL SET THE NETWORKING AGENDA?

The changes in educational practice presaged by the introduction of school computer networking suggest that there may be some significant alterations in the roles of administrators, teachers, and students. Whenever roles and expectations shift, questions arise about the wisdom of proposed changes and their impact on individual security and social equity.

On a very basic level, the introduction of networking entails new some duties and resposibilities. Someone must see to the selection and procurement of equipment and software and the repair and maintenance of systems; someone must take charge of teacher training, planning and evaluation of projects, and establishing and maintaining networking relationships including subscription contracts. Heretofor, these kinds of duties have fallen on the computer-entreprenurial teacher, the one whose enthusiasm often takes the lead as schools become computerized. Local bulletin-board systems, commercial network forums such as The Source and CompuServe, and Computer-Using Educators groups have been crucial in supporting teachers in their efforts to get schools involved in computer use.

As computers become more central to the activities of public schools, and as the cost of computing relative to other budgetary items rises, the need for commitment and support from principals, superintendents, and local school boards becomes more critical. Parents, increasingly familiar with computing in their work, have

been key motivators for getting computing machinery into local schools; their understanding of and support for networking will be important to its long-term success as the focus shifts from one-shot investment in machines to continuous support of activities. Formal and continuing evaluation of the usefulness and effectiveness of networking projects in meeting definable and testable educational objectives may be the key to developing a robust school networking culture.

The additional responsibilities that teachers face in networking operations suggest that public school authorities may want to consider arrangements to help teachers get additional training and to reward them for their efforts in developing new curricula. Networking skills, like computer skills in general, make teachers more attractive to business and industry; master-teacher programs, salary credits for specific competencies, and summer stipends for curriculum development work may be considered as inducements to keep the best computer-networking educators in education. Educators will be challenged to justify to the public the shift of priorities or increases in spending.

Teachers and administrators face additional challenges to their traditional roles with the advent of computer networking. Many of the student activities described in this paper place the student more and more in a leading role in setting his personal and the community's educational agenda. Teachers may become much more the facilitators and advisors of students, more like traditional graduate-level university educators. Administrators

may be confronted with unprecedented institutional arrangements that challenge the traditional notions of hierarchy and local automony in decision-making. School officials may well become international ambassadors pro tempore for American public education.

The potential scale and scope of educational computer networking suggest that the pivotal role played by educator-facilitators will have implications far beyond the classrooms and administrative-office settings that most educators are familiar and comfortable with. Education has recently been an ideological battleground over the content of text books; one might expect that the reach of networks could lead to further and more acute politicization of education. As the vision of "classrooms without walls" is realized, the question of what we are educating children for, and how we are to form a consensus on this crucial issue, takes on a new urgency.[13] Assuming even moderate success in initiating new activities, networking educators eventually are sure to be the focus of intense public scrutiny.

Aside from questions about new roles for students and educators and about the content of network curricula, questions about equity are also likely to accompany the spread of computer networking in education. There are good reasons to believe that under favorable

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13. The politicization of schools has been recognized as implicit in John Dewey's vision of practical education for some time; see, for example, Lawrence A. Cremin, Public Education (New York: Basic Books, 1976), particularly the chapter titled "Public Education and the Education of the Public," pp. 57-77.

conditions networking can extend participation in educational activities to those who have previously been handicapped in various ways. However, the issue of whether students, teachers, and administrators have adequate access to network resources will continue as long as there are inequities in the distribution of wealth among local schools districts. Until every user has equipment and software at home, and there are network services available for free or at minimal cost, there remains a likelihood that the increased capabilities afforded by computer networking will disproportionately benefit the rich.

THE FEDERAL ROLE IN EDUCATIONAL COMPUTER NETWORKING

The emerging system of educational computer communication may be analyzed in functional terms as consisting of three components: ensembles of local computing resources, some institutional frameworks and technological capabilities for organizing and conducting network forums, and communications links between and among local and distant participants. Federal policy may been seen to interact with these components and to turn on a central issue relating to each, offering a variety of options -- ranging from minimal to substantial -- for government intervention in the evolution of the system.

LOCAL COMPUTING RESOURCES: THE ACCESS ISSUE

The threshold question relating to local computing resources concerns the conditions of access that different participants in different localities will have to the range of available network activities. This will be determined, to a large extent, by the number and quality of hardware and software facilities available to participants. Central to the federal role in the access issue, should the government decide that computer networking is a desirable adjunct to public education, is the question of equity: What can the federal government do to see that access to this emerging educational technology is reasonably equitable?

Minimal:

Make sure that every school district has some access to networking facilities. This is occurring in many locales without federal help; but the government may, with a relatively small investment, make sure that poorer schools have the basics.

Intermediate:

Earmark a greater amount of funding to the purchase and upgrade of networking equipment and software in schools. Fund R&D to determine needs and implement solutions that will improve school usage of computer-networking systems.

Substantial:

Initiate a major federal program to promote computer networking as a remedy for current inequities in public education. Assume the leadership in raising the profile of school networking in the public eye, and devote substantial funds to capitalizing the public school system.

NETWORK FORUMS: THE REPRESENTATION ISSUE

The threshold question relating to the institutional structures and technological capabilities that support network forums concerns the issue of what interests will be represented in school networking activities. This will be determined, to a large extent, by perceptions about what can be gained in organizing these activities. Central to the federal role in the representation issue is the question of the agenda of values: What can the federal government do to see that the interests of a diversity of educational and social goals are represented in school networking?

Minimal:

Observe the evolution of school networking; be sensitive to the needs of minorities, providing for their participation through existing equal-opportunity and affirmative-action mechanisms. Make sure that federal First Amendment, intellectual property, and privacy policies keep pace with the emerging requirements of computer network operations.

Intermediate:

Fund R&D in a range of networking efforts, spanning a diversity of subject matter. Science education is the subject of a number of emerging network forums; the federal government may justify

intensifying this effort on "national security" and "international competitiveness" grounds. Reading, writing, and research skills are also promising avenues for development, as are efforts in developing community problem-solving and conflict-resolution skills. Initiate and/or coordinate new projects; organize and/or fund pilot demonstrations.

Substantial:

Develop a full-scale national effort to promote, develop and operate computer-networking forums for education. The federal government may see long-term advantages in taking a leadership role in what many believe to be a revolution in economic and social life. To the extent that private (for-profit and not-for-profit) ventures and state and local government efforts are inadequate to encompass and balance national- and global-scale social interests in computer networking, the federal government may see a role as patron of network forums.

COMMUNICATIONS LINKS: THE COST/BANDWIDTH ISSUE

The threshold question relating to communication links among the participants in school computer networking concerns the cost of securing different levels of service -- in terms of speed and

format.[14] This will be determined, to a large extent, by the technical infrastructure and the pattern of institutional control (e.g. competition and pricing) in existing communications media. Central to the federal role in the cost/bandwidth issue are questions concerning which activities can be supported and the volume of network activity that schools may afford using computer networks: What can the federal government do to maximize the educational benefits that schools can obtain from their expenditures on communication services?

Minimal:

See to it that rates are not set by unrestrained monopolies over communication services. Schools currently have a number of options for minimizing their telephone bills, including packet networks and low-rate night calling; nevertheless, educators generally find their communications budgets quickly depleted every month as their demand for communication services is increasing. Pay close attention to the changing telecommunciations industry structure and on changes in its pricing of services that are critical to school networking.

Intermediate:

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[14] For example, narrow-band systems such as those commonly employed in existing personal-computer-modem networks are adequate for the transmission of text; wide-band systems are required for the transmission of digital graphics or analog television signals.

Encourage a special rate structure for public-school communication services. Fund state and local efforts to develop special school-based telecommunication systems in which bulk-rate services are purchased for school use, or bypass technology (e.g. terrestrial or satellite microwave) is put into place for school districts. The Public Broadcasting System may serve as a model for federal support of community-based communication services. The Federal Communications Commission has long been required to set aside substantial spectrum space for educational use; this resource has thus far been underutilized, but it is now being sought after by commercial interests; perhaps arrangements between governement and industry could be made to satisfy both public and private interests.

Substantial:

Recognizing that improvements in education are essential to the future health and security of the country, and believing school computer networking to be a significant avenue of improvement, the federal government might make the establishment of a low-priced, high-bandwidth, government-financed public school telecommunications network a priority. The defense community has been successful in implementing ARPANET; the education community may produce convincing arguments that a similar -- though certainly larger-scale -- effort is now appropriate for public education.

APPENDIX: CONCEPTUAL FRAMEWORK FOR EDUCATIONAL COMPUTER NETWORKING

As we have seen, computer communication is becoming a useful and versatile tool for education at the K-12 level for students, teachers, and administrators. Adoption of the technology is at a formative stage, and a complete picture of how it will be integrated into educational practice is, at this point, speculative. However, our investigation has identified some attributes of the most promising efforts. Organizing these attributes with a theoretical orientation borrowed from Dewey and Piaget, we may project a conceptual framework highlighting the functional relationships emerging in successful school computer networking. Key characteristics include:

- sufficient financial and staff resources dedicated to supervising and maintaining network operations;

- recognition that participants must perceive the network to be directly useful to their personal and organizational objectives;

- clear guidelines for network usage, leaving reasonable latitude for the participants to experiment and to develop their own methods of interacting;

- an evolving range of network subject matter to challenge and develop participants' aptitudes and interests, emphasizing the connection between the learning of skills and knowledge and the

solution of real-world problems to which participants may contribute;

- a systematic and flexible progression of activities to help initiates get involved, to hold the attention of advanced users, and to encourage the development of responsibility for network operations. [Insert Fig. 2 here]

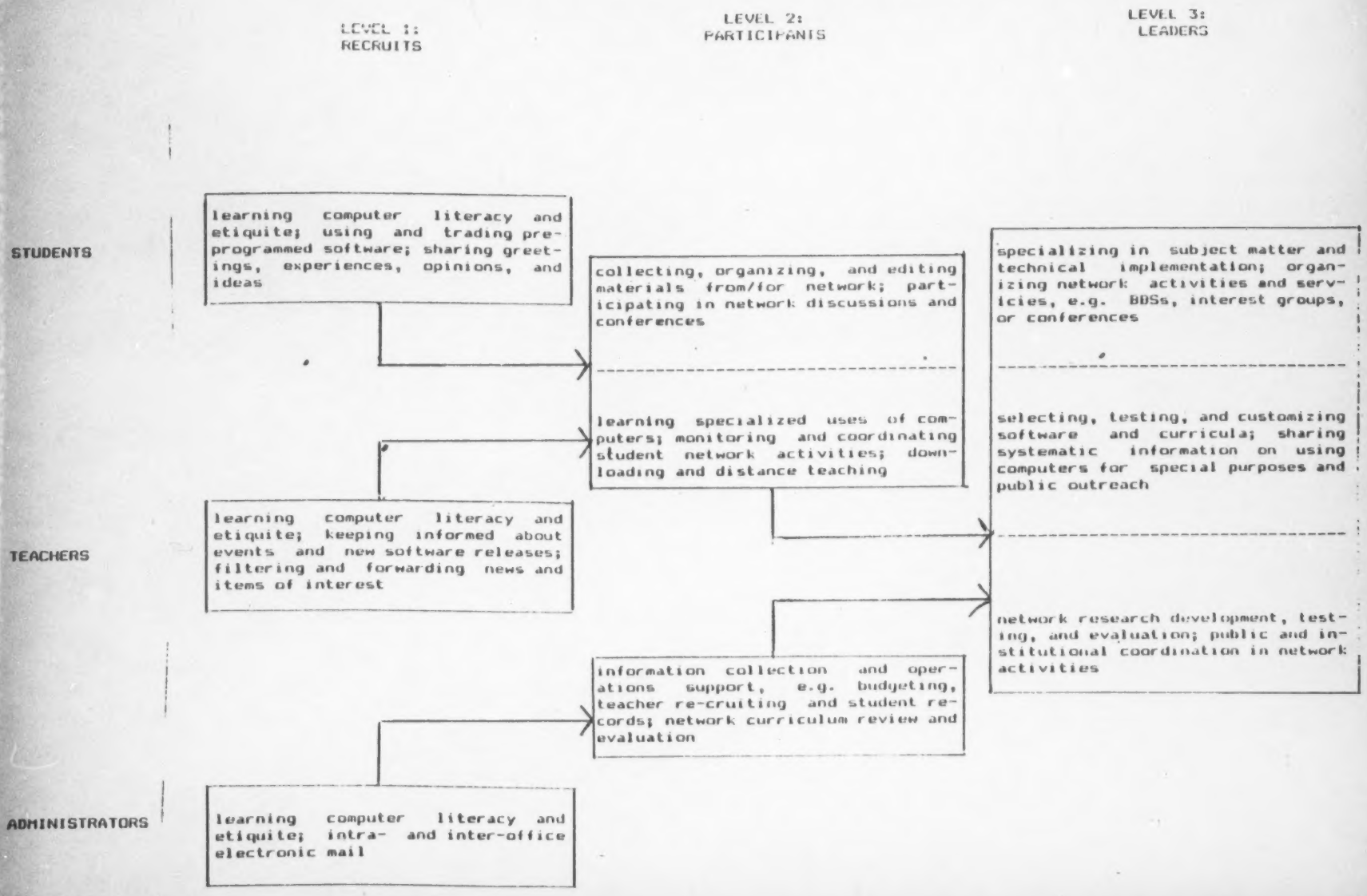
OPERATIONAL DEFINITIONS

To understand how these general functional characteristics may be incorporated into practice, some definitions are helpful. One may identify three fundamental sources of contingency criteria -- "dos and don'ts" -- which influence the implementation of educational communications:

Institutions:

Social organizations that exist to apply collective intelligence and effort to distinctive problems of community life. For example, educational institutions (schools) are primarily concerned with the development of knowledge and skills in people; elementary and secondary schools are primarily concerned with the development of the young. In carrying out their operations, institutions establish contingency criteria based on the values that practice has shown advance primary institutional interests; officials exercise the authority to evaluate participants' performance and to enforce these values -- "shoulds and should nots" -- by granting or withholding

FIGURE 1: PROGRESSION OF INVOLVEMENT IN EDUCATIONAL NETWORKING


LEVEL 1:
RECRUITS
LEVEL 2:
PARTICIPANTS
LEVEL 3:
LEADERS
STUDENTS
learning computer literacy and etiquite; using and trading pre-programmed software; sharing greetings, experiences, opinions, and ideas
collecting, organizing, and editing materials from/for network; participating in network discussions and conferences
specializing in subject matter and technical implementation; organizing network activities and servicies, e.g. BBSs, interest groups, or conferences
TEACHERS
learning computer literacy and etiquite; keeping informed about events and new software releases; filtering and forwarding news and items of interest
learning specialized uses of computers; monitoring and coordinating student network activities; downloading and distance teaching
selecting, testing, and customizing software and curricula; sharing systematic information on using computers for special purposes and public outreach
ADMINISTRATORS
learning computer literacy and etiquite; intra- and inter-office electronic mail
information collection and operations support, e.g. budgeting, teacher re-cruiting and student records; network curriculum review and evaluation
network research development, testing, and evaluation; public and institutional coordination in network activities

institutionally sanctioned rewards, privaleges, and punishments.

Medium:

A medium is a channel of communication within and among institutions (the home may be considered an institution). Media are distinguished from one another by the inability to pass certain forms of information between them; they are also distinguished by the tasks that people may easily accomplish with them, and thus by the skills required to use them for various purposes. Operationally, media impose contingency critieria -- "mays and may nots" -- related to their use characteristics. For example, radio and television are distinctive media because they impose different technical constraints on, and favor peculiar variations in, the forms users may manipulate; the same is true for two computer systems with incompatible software.

Subject Matter:

The content of human discourse, subdivided so as to make possible its efficient assimilation by people seeking knowledge for a given purpose. Subject matter contigencies operate through the preferences of users. Subject matter, for the purposes of learning, may be distinguished in terms of "wills and will nots," because an individual's experiences will influence the usefulness and that he attaches to different items of content, and thus affect his readiness and motivation to embrace them.[15] [Insert Fig. here]

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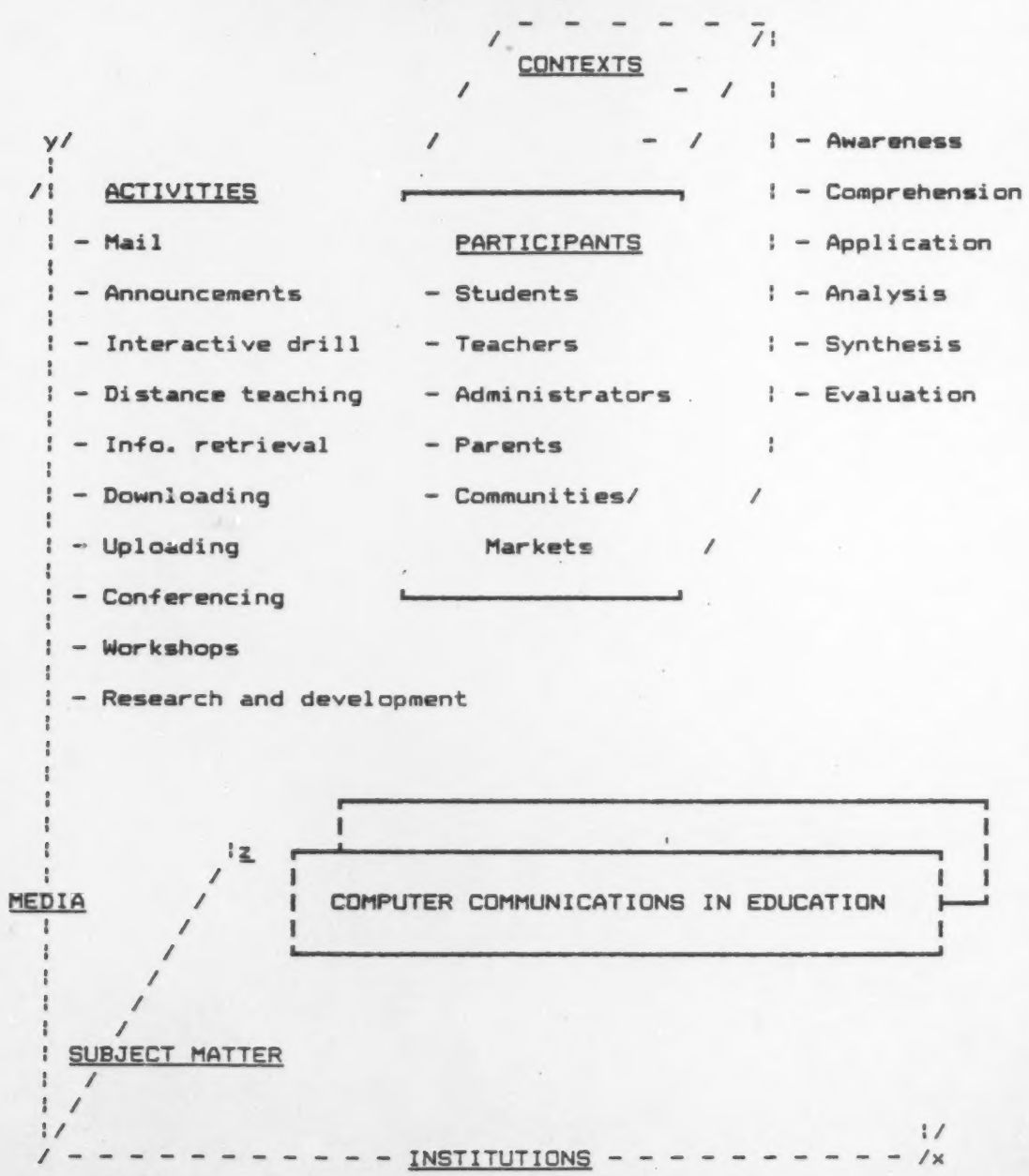
[15]. Dewey, op. cit., pp. 169, 170, 173, 186; see also Milton Chen and William Paisley (eds.), Children and Microcomputers (Beverly Hills, CA: Sage, 1985), p.50.

FIGURE 2: ANALYSIS OF THE INTERACTION
OF INSTITUTIONS, MEDIA, AND SUBJECT MATTER



Source: OTA; Earl Dowdy, Contract Number H3-4095.0, 1987.

OPERATIONAL BALANCES

In designing a network strategy, educators must determine the conditions under which communications through their system may take place. The constraints of budget resources, staff time, scope and scale of participants and activities, the nature and pace of skills acquisition, and applicable laws and policies all interact in setting limits on what users can do with the system. As our investigation has shown, institutions, media, and subject matter may be arranged so as to produce a set of input and output conditions that favor balanced networking practice:

Input:

"Who on my system may access and use what out there for what purpose?"

Who: Media/Institutions ==> Local Participants

Media (form) input is organized according to source institution to determine local participants. Definite rules, and conditions of appeal, are established allocating time on local resources among qualified users for specified purposes. This allows officials to control network costs and uses within their own institution.

What: Subject Matter/Media ==> Local Activities

Subject matter (content) input is organized according to source medium to determine local activities. Care is taken to match the media available for instruction and operations support to the appropriate subject matter. Nothing is more frustrating than trying

to adapted a medium to activities for which it is not well suited; not all subject matter is necessarily suited to networking, only experimentation in a supportive environment can tell. The connection of various subjects and the translation of various media in a single project can produce the most surprising and useful results.[14]

Why: Institutions/Subject Matter ==> Local Contexts

Institutional (authority) input is organized according to subject matter to determine local contexts. Rules for usage are made appropriate to the requirements of particular work. This encourages respect for authority, as it demonstrates rules to be practically motivated rather than arbitrary.

OUTPUT:

"Who out there may access and use what on my system for what purpose?"

Who: Institutions/Media ==> Distant Participants

Institutional (authority) output is organized according to media to determine distant participants. To enjoy the expanded horizons made possible by networking, the system allocates sufficient resources to attract outside participants; as well, officials are assured that certain uses are restricted so as to protect the integrity of information. Access rules are therefore specified in terms of

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14. This has been a central finding of much research on multimedia education; see, for example, Wilber Schramm, Big Media, Little Media (Beverly Hills, CA, 1977), and Patricia Marks Greenfield, Mind and Media: The Effects of Television, Video Games, and Computers (Harvard University Press, Cambridge, MA, 19

specific system features, and passwords or other media barriers control access so that usage may be commensurate with the interests and authority of participants.

What: Media/Subject Matter ==> Distant Activities

Media (form) output is organized according to subject matter to determine distant activities. The system is compatible with and able to support activities that pique the interests of users in subjects they are currently concerned with. Projects are organized to match the scale and form of communication to the questions under study.

Why: Subject Matter/Institutions ==> Distant Contexts

Subject matter (content) output is organized according to institutional destination to determine distant contexts. The effectiveness of educational communication depends upon the nature of the subject matter under study and how that subject matter relates to specific personal and institutional objectives. Considering the importance of self-motivation in developing meaningful communication,[17] officials recognize the broad range of goals to be served when they make agreements with other institutions for collaboration in networking efforts.

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17. Dewey, op. cit., pp.130-135 and 153-154; in the context of computers see Chen and Paisley, op. cit., pp.51-52.

SOCIAL CHECKS

In the larger contexts of communities and markets, boundaries must be respected for educational networking operations to harmonize with overall social goals. Educators and students recognize reasonable limits to usage to assure that all interests are given fair hearing in educational computer networks:

"Who may communicate what through my system with whom for what purpose?"

Subject Matter provide content for participants; therefore, personal privacy and community security must limit subject matter.

Institutions provide authorization for activities; therefore, civil rights and due process must limit institutions.

Media provide form for contexts; therefore, explicit access/distribution/use restrictions (e.g. passwords, charges, copyrights) -- not only technical incompatibilities -- must limit media.